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SOLAR WIND ARGON FROM GENESIS ALOS REGIME COLLECTORS

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Introduction: Determining solar noble gas isotopic ratios are one piece of the puzzle needed to constrain models of the evolution of terrestrial planets, as well as to understand solar composition and processes. Solar wind (SW) remains the best available source of solar material, even though there is potential for fractionation between true solar values and the solar wind. Here we will focus on SW argon.

In 1974 Cerutti analyzed Apollo SWC foils and found a $^{36}Ar/^{38}Ar$ ratio that could not be resolved from the terrestrial value of 5.3 [1]. But with examination of lunar soils, a difference between solar and terrestrial Ar emerged. Unfortunately, analysis of these soils produced varying results, from 5.48 [2] to 5.80 [3]. With Genesis Aluminum on Sapphire (AloS) samples, we are now able to precisely define the solar wind value and clearly differentiate it from the terrestrial value.

Results: Previously reported Ar data [4] are now confirmed by additional measurements. These measurements were made using samples of bulk SW and the three individual SW flow regimes: interstream SW (low-speed), coronal hole SW (high-speed), and coronal mass ejections (CME). The averages of the isotopic ratio, ^{36}Ar flux, and $^{20}Ne/^{36}Ar$ ratio for each regime are given in the table below. Errors shown for $^{36}Ar/^{38}Ar$ ratios are 1σ statistical errors; for the ^{36}Ar flux and $^{20}Ne/^{36}Ar$ ratios, the numbers in parentheses are uncertainties based on the spread in the measured amounts ^{36}Ar and ^{20}Ne.

Table 1.

Sample	$^{36}Ar/^{38}Ar$	^{36}Ar flux ($10^6/m^2 \cdot s$)	$^{20}Ne/^{36}Ar$
Bulk SW	5.501 ± 0.005	3.81 (0.2)	59 (5)
High-speed	5.502 ± 0.010	2.78 (0.1)	66 (6)
Low-speed	5.508 ± 0.010	3.63 (0.4)	46 (5)
CME	5.467 ± 0.017	3.68 (0.8)	59 (4)
Terr. atm. [5]	5.319 ± 0.008	–	0.524
Terr. atm. [6]	5.305 ± 0.008	–	–

Discussion: These results define the bulk SW $^{36}Ar/^{38}Ar$ ratio to be 5.501 ± 0.005, (with similar precision as the terrestrial value), which is 3.40 ± 0.09% lighter than terrestrial atmospheric Ar. This has implications for atmospheric retention models. Coulomb Drag Theory predicts a small isotopic fractionation between the low- and high- speed SW regimes [7]. Our data restricts this to less than 0.6% for the $^{36}Ar/^{38}Ar$ ratio. Differences between the flow regimes of the $^{20}Ne/^{36}Ar$ ratio suggest elemental SW fractionation, with the low-speed SW ~25% heavier than the other regimes. This probably reflects differences in the efficiency of the FIP effect in the different SW flow regimes.

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DISTRIBUTION OF Al-Mg MODEL AGES FROM INDIVIDUAL MINERALS IN A SPINEL-BEARING CHONDRULE FROM ALLENDE

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The timing of formation and thermal processing of chondrules plays an important role in models of early solar system evolution. The inferred uniform distribution of short-lived radionuclide ^{26}Al in the inner solar system [1] makes ^{26}Al-^{26}Mg systematics a powerful relative chronometer of the nebular and early asteroidal processes. Al-Mg isochrons in chondrules are commonly defined by the phases with low Mg contents (glass and anorthite). Although Al-Mg systematics in these phases can be easily disturbed during thermal metamorphism, resulting in Mg-isotope equilibration and lower $(^{26}Al/^{27}Al)_0$ [2–4], a degree of this disturbance is difficult to evaluate quantitatively. In contrast, Mg-isotopic resetting in spinel occurs by Mg-self-diffusion, the speed of which is similar to that of Fe-Mg intradiffusion; the latter can be easily detected in thermally metamorphosed chondrites (petrologic type >3.2) and quantitatively evaluated using compositional profiles [5]. Fe-free regions of spinel crystals must preserve their original Mg-isotopic compositions. Spinel is often a liquidus phase in igneous CAIs [6] and Al-rich chondrules [7] and can be used to date their crystallization age.

Experimental: Mg-isotopic compositions of chondrule spinel were measured with the TiTech Cameca IMS 1270 ion probe by a mono-collector Faraday cup; spot size of primary O^{2-} beam was ~30 µm. Spinel from Russia and augite from Takashima were used as standards for determination of terrestrial isotope ratios of Mg and of the instrumental mass fractionation and the matrix effects. Assuming a reference values for $^{25}Mg/^{24}Mg$ as 0.12663 [8], the $^{26}Mg/^{24}Mg$ are determined as 0.1393611 ± 0.0000099. The deviation in the measured $^{26}Mg/^{24}Mg$ ratio from the reference value was obtained by observed mass fractionation factor under an assumption of linear mass fractionation law: $\Delta^{25}Mg = 0.51622 \times \Delta^{26}Mg$, where $\Delta^{25,26}Mg = [\{(^{25,26}Mg/^{24}Mg)_m/(^{25,26}Mg/^{24}Mg)_{ref}\}-1] \times 1000$. Precision of $^{26}Mg^*$ measurements in spinel is <0.4‰.

Results: The Allende BO chondrule A1-2b-1 (A1) consists of olivine, low-Ca pyroxene, feldspathic mesostasis, and a coarse (200 µm), Fe-free spinel grain. A regression of six measurements from the spinel show $^{26}Mg^*$ corresponding to the initial $^{26}Al/^{27}Al$ ratio of $(1.50 \pm 0.70) \times 10^{-5}$ (forced through the origin). O-isotopic compositions of spinel in A1 reported by [9] is ^{16}O-depleted ($\Delta^{17}O = -7.1 \pm 0.9$‰) relative to those from the Allende CAIs. We infer that spinel crystallized from the host chondrule melt and is not a relict CAI grain. The inferred $(^{26}Al/^{27}Al)_0$ in spinel corresponds to the crystallization time of the host chondrule: ~1.25 My after formation of CAIs with the canonical $(^{26}Al/^{27}Al)_0$ of $\sim 5 \times 10^{-5}$. In contrast, the feldspathic mesostasis in A1 shows no resolvable $^{26}Mg^*$ ($[^{26}Al/^{27}Al]_0 = [1.6 \pm 9.8] \times 10^{-6}$) [9]; this may reflect disturbance of Al-Mg systematics in mesostasis during fluid-assisted thermal metamorphism. Our results indicate that Al-Mg systematics in spinel can be used to constrain crystallization time of chondrules from meteorites experienced thermal metamorphism. It seems plausible that relict spinel grains in chondrules may have preserved $(^{26}Al/^{27}Al)_0$ of their source materials (chondrules of earlier generations or CAIs).

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